Coplanar waveguide probe

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Abstract of **GB2197081**

A coplanar waveguide probe comprises a dielectric substrate (8) having a pattern of ground electrodes (4) and signal electrodes (6) arranged on one surface. An electrically conductive layer (12) on a further surface of the substrate is in electrical contact with the ground electrodes (4) contact being by way of a series of via holes (18) containing electrically conductive material (20), such as gold or conductive epoxy, and/or an extension portion (14) of the electrically conductive layer.

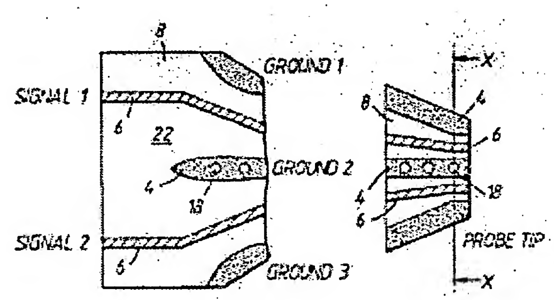

FIG. 3.

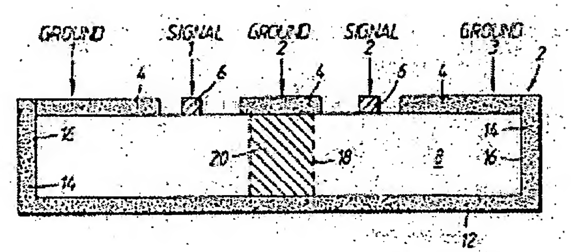

FIG. 4.

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(54) Coplanar waveguide probe

(57) A coplanar waveguide probe comprises a dielectric substrate (8) having a pattern of ground electrodes (4) and signal electrodes (6) arranged on one surface. An electrically conductive layer (12) on a further surface of the substrate is in electrical contact with the ground electrodes (4) contact being by way of a series of via holes (18) containing electrically conductive material (20), such as gold or conductive epoxy, and/or an extension portion (14) of the electrically conductive layer.

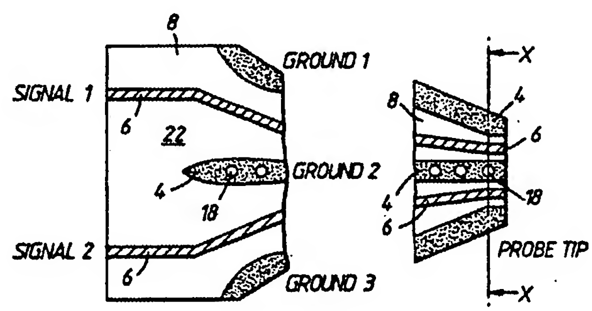

FIG. 3.

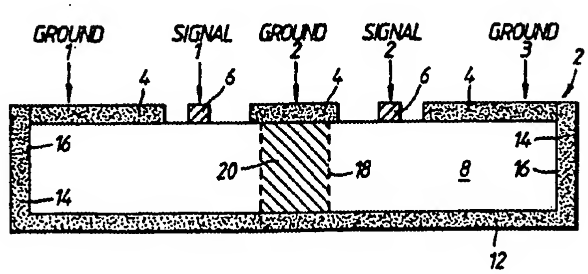

FIG. 4.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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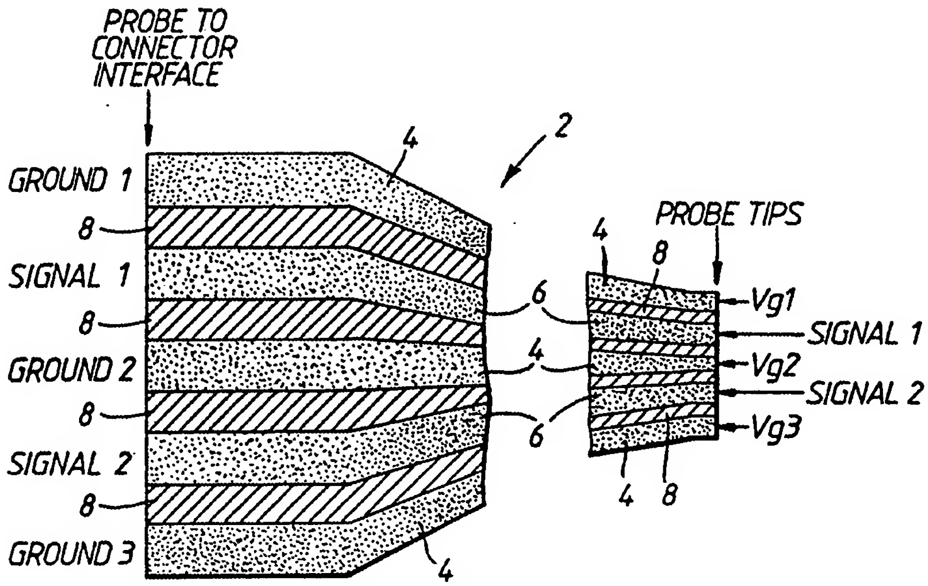

FIG. 1.

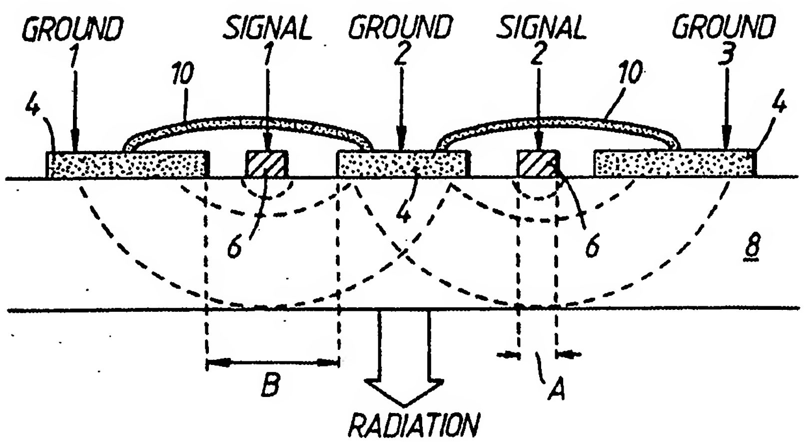

FIG. 2.

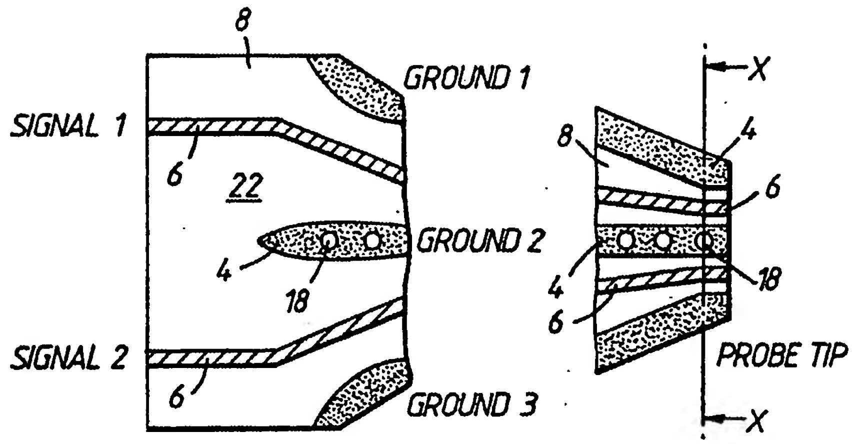
8
GROUND 1
SIGNAL 1
6
22
GROUND 2
4
18
SIGNAL 2
6
GROUND 3
X
8
4
6
4
18
6
PROBE TIP
X

FIG. 3.

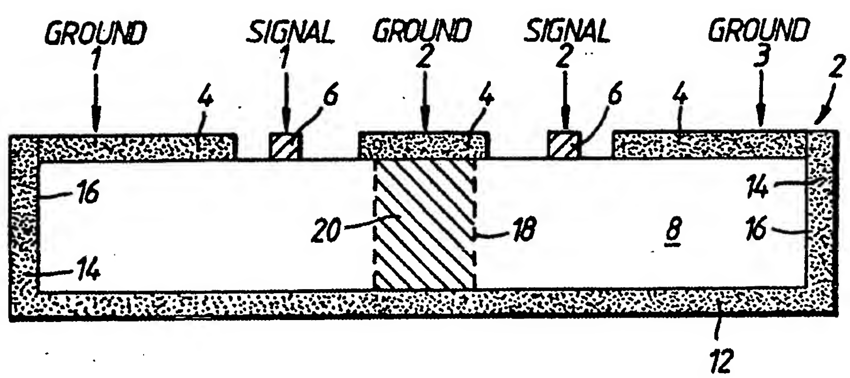
GROUND 1
SIGNAL 1
GROUND 2
SIGNAL 2
GROUND 3
2
4
6
4
6
4
16
14
20
18
8
14
16
12

FIG. 4.

SPECIFICATION

Probes

The present invention relates to improvements in or relating to probes and in particular, to coplanar waveguide probes which can be used to measure the performance of integrated circuits.

To minimise circuit testing and hence production costs and time scales, it is desirable to measure the functionality of every integrated circuit on a wafer of circuits before that wafer is divided to produce the individual integrated circuit chips. This procedure is known as "on wafer" circuit testing. For relatively low frequency silicon integrated circuits "on wafer" circuit testing is carried out by using conventional probe cards, as is well known in the art. However, the inductance of the individual probes and the inter-probe capacitances inherent to the needle-like structures prevent meaningful measurements at frequencies much above 10MHz. Some recent generations of silicon integrated circuits are capable of functioning at frequencies above 2 GHz and gallium arsenide circuits can achieve frequencies of 18 GHz and above. It can be seen, therefore, that there is a real need for wafer test equipment capable of reliable and meaningful radio frequency (r.f.) measurements to at least 18 GHz.

To perform "on wafer" r.f. measurements at these frequencies with meaningful accuracy, a probe system must be used which can provide a low loss, closely matched (low input voltage standing wave ratio) signal path from the measurement equipment to the r.f. input and output connecting pads of the integrated circuits under test. Attempts have been made to refine conventional probe cards and, whilst these devices can operate at frequencies up to about 4 GHz, they suffer from the same inductance limitations of the earlier probe cards at higher frequencies. These devices are described in detail in "A Microwave Probe System" by D. Hornbuckle et al, Proceedings of Hewlett Packard R.F. and Microwave Symposium, Munich 1983.

In view of the shortcomings in the refined probe cards, coplanar waveguide probes have been developed which utilise a coplanar waveguide as the probe transmission media at microwave frequencies up to about 18 GHz. Such a device is described by K.R. Gleason et al in "Precise MMIC parameters yielded by an 18 GHz Wafer Probe", Microwave Systems News, May 1983, pages 55–65.

It is an object of the present invention to provide an improved coplanar waveguide probe.

According to the present invention there is provided a coplanar waveguide probe comprising a dielectric substrate, a ground electrode and a signal electrode arranged on a surface of the substrate in spaced relationship, an electrically conductive layer arranged on a further surface of the dielectric substrate, and electrically conductive means for electrically connecting the ground electrode to the electrically conductive layer.

The electrically conductive layer may extend into contact with the ground electrode so as to provide the electrically conductive means.

Advantageously, the conductive means for electrically connecting the ground electrode to the electrically conductive layer may comprise a via hole, containing electrically conductive material, extending through the dielectric substrate spacing the ground electrode from the electrically conductive layer.

Conveniently, the conductive means for electrically connecting the ground electrode to the electrically conductive layer may comprise a via hole, containing electrically conductive material, extending through the dielectric substrate spacing the ground electrode from the electrically conductive layer in combination with the electrically conductive layer extending into contact with the ground electrode.

The electrically conductive material contained in the via hole may comprise conductive expoxy.

The electrically conductive material contained in the via hole may comprise a coating of metallic material.

The electrically conductive material contained in the via hole may comprise a filling of metallic material.

Benefically the conductive layer comprises a metallised layer.

The metallised layer may comprise gold.

The metallic material contained in the via hole may comprise gold.

Advantageously, the conductive means for electrically connecting the ground electrode to the electrically conductive layer comprises a plurality of via holes each containing electrically conductive material, the cross sectional area of any via hole being dependent upon the spacing of the via hole from the tip of the probe.

Conveniently, the ground electrode does not extend the length of the probe and the end thereof remote from the tip of the probe is of a predetermined tapered shape.

In a preferred embodiment the probe comprises a pattern of signal electrodes and ground electrodes, a ground electrode being disposed on and spaced from either side of each signal electrode and wherein the outermost ground electrodes are in contact with the electrically conductive layer extending around the dielectric substrate and the remaining ground electrodes are electrically connected to the electrically conductive layer by means of via holes containing electrically conductive material.

Advantageously, the dimensions and spacing of the ground and signal electrodes are such

that the probe exhibits a characteristic impedance of approximately 50 throughout its length.

The dielectric substrate may comprise alumina.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings in which

Figure 1 illustrates a generally schematic plan view of a coplanar waveguide probe;

Figure 2 illustrates a generally schematic end view of a known coplanar waveguide probe;

Figure 3 illustrates a generally schematic plan view of a coplanar waveguide probe in accordance with the present invention; and

Figure 4 illustrates a generally schematic cross sectional view through the line X–X of the probe shown in Fig. 3.

In the following description like reference numerals have been used to indicate like elements of the probes.

Essentially, coplanar waveguide permits the relatively large dimensions of transmission lines required to interface with 50Ω characteristic impedance measuring equipment to be transformed to the typical 100 to 150 micron feature sizes encountered on integrated circuits. As can be seen from Figs. 1 and 2 a coplanar waveguide probe 2 comprises a planar pattern of metal ground electrodes 4 and signal electrodes 6 printed on a dielectric substrate 8, such as an alumina substrate. The ground and signal electrodes 4, 6 are disposed on the substrate 8 such that each signal carrying electrode 6 is placed symetrically in the space between two ground electrodes 4, as shown in Fig. 1. A constant characteristic impedance of 50Ω, to match that of the test equipment, is achieved along the length of the probe 2 by maintaining a fixed relationship between the width A of the signal electrodes 6 and the spacing width B between the ground electrodes 4, as shown in Fig. 2. It is important, however, that the ground electrodes 4 are kept at the same r.f. ground potential to provide any meaningful measurement of the integrated circuit under test, that is, $Vg1=Vg2=Vg3$. Unfortunately, as can be seen from Fig. 1, there is no inherent connection between the ground electrodes 4 and hence, the ground electrodes are shorted together only at the connector interface end of the probe. Thus, at microwave frequencies the tip of the probe may be up to about 10 wavelengths away from the shorted ground connections and so the potentials of the ground electrodes at the probe tip may not be equal. In prior devices this problem has been alleviated by bonding wire or tape loops 10 between the ground electrodes 4, as shown in Fig. 2 or by the use of nickel channel bridges extending between the ground electrodes (not shown). In view of the small dimensions involved, the wire loops 10 or nickel bridges (not shown) are very costly and very time consuming to fabricate and, furthermore, the wire loops 10 are very susceptible to mechanical damage during handling and/or use. Additionally, in view of the very small spacing and overall dimensions at the probe tip, such wire loops 10 or nickel bridges may be formed at a compromise distance from the probe tip. The ground shorts may, therefore, still be a few wavelengths from the probe tip. Hence, the potentials of the ground electrodes 4 at the probe tip may not be as closely matched as is possible in spite of the expensive attempts to remedy this problem, giving rise to measurement errors.

Errors may also arise from radiation through the back of the substrate, as shown in Fig. 2.

In developing the present invention it has been found that the electromagnetic fields generated between the ground and signal electrodes 4, 6 are not wholly confined in the dielectric medium of the substrate 8 and hence, there is r.f. radiation from the back of the substrate. The resultant leakage can give rise to measurement errors and may degrade the isolation between the measurement channels. Furthermore, if the test equipment is to be used in a production environment, as is possible for "on wafer" testing, the probes may be exposed to and be susceptible to stray r.f. radiation from other wafer processing equipment, such as ion implanters, r.f. sputtering apparatus etc. This exposure of such probes to stray r.f. radiation may give rise to further errors in measurement.

The problems with known designs of coplanar waveguide probe can be alleviated by means of the coplanar waveguide probe in accordance with the present invention, an example of which is shown in Figs. 3 and 4.

As with known devices, the coplanar waveguide probe 2 in accordance with the invention comprises a pattern of spaced ground and signal electrodes 4, 6 on the surface of a dielectric substrate 8. An electrically conductive layer, such as metallisation layer 12 which may comprise gold, is provided as a backing layer to the dielectric substrate 8. The metallisation layer 12 is grounded by connection to the ground electrodes 4. In the embodiment illustrated by Fig. 4 this is achieved by electrically conductive means such as a wrap 14 of electrically conductive material around each side edge 16 of the dielectric substrate 8. The wraps 14 may be formed as extensions of the metallisation layer 12. The inclusion of the grounded back metallisation layer 12 confines the r.f. fields in the probe and prevents any radiation from the back of the dielectric substrate 8. Thus, the inter channel isolation of the probe 2 is dramatically improved when compared to known devices. Furthermore, there is no leakage from the rear of the probe to degrade the r.f. measurements and the probes are less prone to r.f. inerfer-

ence from adjacent processing equipment, thereby providing more meaningful measurement of the parameters of the integrated circuits under test.

The back metallisation layer 12 also provides a convenient means of providing a common potential for the ground electrodes 4 which can not contact the metallisation layer by means of the wraps 14. The dielectric substrate 8 is of the relatively thin thickness, typically about 0.25 mm, and hence, a very short ground return path may be achieved by drilling via holes 18, such as by laser drilling, from the front to back surface of the dielectric substrate 8 as shown in Fig. 4. The electrically conductive means may then be located within the via holes 18, such as a filling of conductive epoxy resin 20, to form the ground return path between the metallisation layer 12 and the ground electrodes 4.

Several via holes 18 may be drilled through the dielectric substrate 8 for each ground electrode 4 to provide ground return paths throughout the lengths of the ground electrodes, as shown in Fig. 3, thereby ensuring that the ground electrodes have virtually equal potential to each other throughout their lengths. A laser drilled via hole may be positioned as close as is practicably possible to the tip of the probe 2 to ensure that the ground electrodes 4 have common potential at the tip where interconnection with the integrated circuit under test occurs. To ease fabrication of the probe the size of the via holes 18 may be increased as the width of the ground electrodes 6 increases with spacing from the probe tip.

In addition, the provision of the metallisation layer 12 enables the ground electrodes 4 to extend only a limited length of the probe 2. This is because in the region 22 shown in Fig. 3 the spacing between the signal electrodes 6 and the ground electrodes 4 to maintain the 50Ω characteristic impedance is large when compared to the thickness of the dielectric substrate 8. Hence, the isolation between the signal electrodes 6 and the metallised layer 12 is less than the soilation between the ground and signal electrodes. Therefore, from the region 22 to the probe interface with the test equipment connectors, the waveguide is, effectively, formed by the signal electrodes 6 in combination with the metallised layer 12. This interchange between the ground electrodes 6 and the metallised layer 12 as the effective waveguide ground electrode can be smoothed by providing the ground electrodes 6 with end portions of predetermined tapered shape, as shown in Fig. 3.

It can be seen therefore that a coplanar waveguide probe in accordance with the present invention provides, when compared to known devices, improved electrical isolation and probe radiation performance and hence, improved measuring accuracy. Furthermore, the probe is easier to fabricated than known designs and is more robust in use.

Although the present invention has been described with reference to a particular embodiment it should be noted that modifications may be effected within the scope of the invention. For example, the metallisation layer 12 preferably comprises gold but any electrically conductive material may be used. Additionally, the electrically conductive means in the via holes 18 may comprise a coating or filling of metallic material, such as gold. Furthermore, although a two channel device has been described, the probe may have any number of signal electrodes. Also, the ground return paths to all ground electrodes may be provided exclusively by means of via holes and not the combination of via holes and conductive wrap arounds, as described. Moreover, the metallisation layer 12 may not comprise the exterior backing layer of the probe. Further layers may be provided over the metallisation layer.

CLAIMS

1. A coplanar waveguide probe comprising a dielectric substrate, a ground electrode and a signal electrode arranged on a surface of the substrate in spaced relationship, an electrically conductive layer arranged on a further surface of the dielectric substrate, and electrically conductive means for electrically connecting the ground electrode to the electrically conductive layer.

2. A probe according to claim 1 wherein the electrically conductive layer extends into contact with the ground electrode thereby to provide the electrically conductive means.

3. A probe according to claim 1 wherein the electrically conductive means comprises a number of via holes, containing an electrically conductive material.

4. A probe according to claim 3 wherein the electrically conductive material comprises metallic material.

5. A probe according to claim 4 wherein the metallic material comprises metallic filling arranged to fill the via hole or holes.

6. A probe according to claim 4 wherein the metallic material comprises a metallic coating on the walls of the via hole or holes.

7. A probe according to any one of claims 4, 5 or 6 wherein the metallic material comprises gold.

8. A probe according to claim 3 wherein the electrically conductive material comprises conductive epoxy.

9. A probe according to any one of claims 3 to 8 wherein the electrically conductive means comprises at least one via hole containing electrically conductive material in combination with the electrically conductive layer extending into contact with the ground electrode.

10. A probe according to any one of

claims 3 to 9 comprising a plurality of via holes for connecting the ground electrode to the electrically conductive layer, the cross sectional area of any via hole being dependent upon the spacing of the via hole from the probe tip.

11. A probe according to any one of the preceding claims wherein the ground electrode does not extend the length of the probe and the end portion of the ground electrode is of a predetermined tapered shape.

12. A probe according to any one of claims 3 to 11 comprising a pattern of signal electrodes and ground electrodes, a ground electrode being arranged on either side of and spaced from each signal electrode and wherein the electrically conductive layer extends into contact with the outermost ground electrodes of the pattern, thereby to connect electricaly the outermost ground electrodes and the electrically conductive layer, and the remaining ground electrodes are connected to the electrically conductive layer by means of via holes containing electrically conductive material.

13. A probe according to any one of the preceding claims wherein the ground electrode or electrodes and the signal electrode or electrodes is/are dimensioned and spaced relative to each other such that the probe exhibits a characteristic impedance of approximately 50 ohms substantially throughout its length.

14. A probe according to any one of the preceding claims wherein the dielectric substrate comprises alumina.

15. A probe according to any one of the preceding claims wherein the metallised layer comprises gold.

16. A coplanar waveguide probe substantially as hereinbefore described with reference to Figs. 3 and 4 of the accompanying drawings.

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